White Paper on

Measuring the Effectiveness and Performance of Multi-Agency Traffic Incident Management Programs

By
Kevin Balke, Ph.D., P.E.
TransLink® Research Center Director
Texas Transportation Institute

Introduction

Incidents continue to be a major source of congestion on our nation's highways. More than one-half of the nation's congestion can be attributed to non-recurring events – either temporary reductions in capacity or events that cause temporary or unexpected changes in traffic demands (*1*). Accounting for approximately 25 percent of the overall congestion problem, vehicle crashes and breakdowns continue to be the primary contributors to this non-recurring congestion problem. Other contributors to the non-recurring congestion problem include work zones (10 percent), inclement weather (15 percent), and special events (5 percent).

Traffic incident management (TIM) has long been viewed as one of the major tools in the traffic engineer's toolbox for fighting the congestion caused by random, unplanned events. Incident management is defined as follows (*2*):

> *…the systematic, planned, and coordinated use of human, institutional, mechanical, and technical resources to reduce the duration and impact of incidents, and improve the safety of motorists, crash victims, and incident responders.*

This coordinated process involves numerous public and private sector partners, each with unique roles and responsibilities, to detect, respond to, and clear traffic incidents and restore capacity as safely and quickly as possible (*3*). While many locations profess to have coordinated TIM programs in place, the results of the Federal Highway Administration's (FHWA's) recent Traffic Incident Management Self Assessment (*4*) suggest that in many locations, TIM functions more as a coalition of different response activities and agencies rather than as a coordinated, cohesive program. In many cases, these "programs" lack a multi-agency, strategic view of where the participating partners want to go and how they plan to get there. This lack of strategic visioning and planning makes it difficult for agencies to sustain TIM over the long term. There is also little consistency as to the best and most appropriate methods of measuring the performance and effectiveness of these programs. Many of the performance measures being used by agencies today do not adequately capture the complexities or provide the comprehensive picture needed to generate long-term political and regional support for the TIM process.

The purpose of this white paper is to discuss some of the issues associated with measuring the performance and effectiveness of TIM programs – not just individual elements or response

agencies within the program, but the entire program. The intent of this white paper is to show agencies the importance of developing and using program-oriented performance measures, and to serve as a starting point for a national dialogue for discussing and developing appropriate and meaningful TIM performance measures. The intent of this effort is to develop a series of measures for evaluating and monitoring the incident management process in an area or region that transcends any the data collection efforts of any one particular agency. This effort is not intended to preclude individual agencies from developing and using performance measures that are specific or unique for their own purposes or actions in the incident management process, but is intended to capture the complex the interactions and coordination that must occur between agencies in order to have effective incident management program in an area. Specifically, this white paper will discuss the following questions and highlight some of the issues from the perspective of the emergency response provider as well as the transportation agency:

- What is a performance measure and why is it important to measure performance?
- What are the important aspects of the incident management process that need to be measured?
- What are some examples of TIM performance measures and why are they measured?
- What are the common institutional and technical issues related to developing and using performance measures for TIM?
- What are some recommendations and suggested "next-steps" that need to occur related to the development of TIM performance measures?

What is a Performance Measure?

The terms "performance measures" and "performance measurements" have been used with increasing frequency over the past decade – sometimes appropriately, but often inappropriately. Because of their widespread use (or perhaps misuse), these two phrases mean different things to different individuals. For the purpose of this white paper, a performance measure is defined as follows (*5*):

> *Factual or measurable evidence that allows agencies to gauge or assess 1) progress towards a predetermined goal (outputs), 2) the quality of those outputs (i.e., how well they were delivered to clients or customers, and the extent to which they were satisfied), or 3) the actual results (or outcomes) of an activity compared to its intended or desired result.*

A good performance measure possesses the following attributes (*5*):

- It reflects what agencies want to accomplish by implementing the system or program. It is derived from agency goals and objectives and allows an agency to determine unequivocally "success" or "failure" at achieving the intended goal and objective. It allows decision-makers to tell how well goals and objectives are being met.
- It is not derived solely from what data are available, but instead drives the type and means of data to be collected.

- It aids decision-makers in making well-informed and appropriate decisions about the effectiveness of the system or program. It provides them with the information they need, with the level of detail, in the appropriate time frame to make informed decisions.
- It provides agencies with the ability to diagnose problems and assess potential outcomes that reveal actual results and not just "level of effort."
- It reflects the interests and desires of all those that have a stake (i.e., the stakeholders) in the system or program. It must be accepted by and meaningful to the stakeholder (whether they are customers, decision-makers, or agency employees).
- It is simple, understandable, logical, and repeatable as well as easy to measure or produce.

In a typical freeway management system, agencies generally employ multiple levels of performance measures and monitoring – each oriented toward a different target audience and used for different purposes:

- **Device- or Component-Oriented Performance Measures –** These types of performance measures are generally geared toward assessing the effectiveness or operation of devices, pieces of equipment, or hardware components. A device- or component-level performance measure might be used to determine when a particular piece of hardware needs replacing or to determine the service life of equipment. An example of this type of performance measure would be the mean time between failures of detection devices. The target audience of these types of performance measures tends to be mid-level managers that are responsible for selecting and maintaining hardware devices and technologies.
- **Operations-Oriented Performance Measures –** These types of performance measures are generally used to assess the day-to-day operations of a system. For incident management systems, these types of measures can be used to detect operational problems that can be classified as an incident. The most common examples of these types of measures are the speed, volume, and occupancy measurements that are collected by surveillance systems. These measures tend to be real-time (or near real-time) and are used by operators to detect when the system (in this case, the freeway) is not operating as expected.
- **Program-Oriented Performance Measures –** Generally, these types of measures tend to be "output"-oriented and reflect general usage of the system. These types of performance measures are commonly used to characterize the operations of a program or functions of an agency. Program-oriented performance measures can also be used to assess the effectiveness of individual programs, to identify deficiencies in those programs, and to evaluate the effectiveness of changes to those systems or programs. Examples of this type of performance measure include the number of incidents detected by a particular detection system and average response time. These types of performance measures are often used by mid-level managers and decision-makers.
- **Agency Mission-Oriented Performance Measures –** These types of performance measures are generally used to rate the performance of the agency toward community-wide goals and desires. These measures are used to identify, analyze, and prioritize improvements and to provide economic justification for continuing or expanding existing programs. Generally, these types of performance measures are used by high-level policy- and decision-makers to assess the benefits and costs associated with performing specific functions an agency performs.

What is an "Incident"?

The term "incident" has many different connotations to the agencies often involved in the incident management process, depending upon their perspective and role in the incident management process. Transportation agencies tend to think of an "incident" as being any event – either planned or unplanned – that affects traffic flow on a transportation facility. FHWA's *Traffic Incident Management Handbook* (*2*) defines an incident as follows:

> *… any non-recurring event that causes a reduction of roadway capacity or an abnormal increase in demand. Such events include traffic crashes, disabled vehicles, spilled cargo, highway maintenance and reconstruction projects, and special non-emergency events (e.g., ball games, concerts, or any other event that significantly affects roadway operations).*

Similarly, the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD) (*6*) defines an incident as follows:

> *… an emergency road user occurrence, a natural disaster, or other unplanned event that affects or impedes the normal flow of traffic.*

Conversely, emergency service responders and law enforcement agencies typically define an incident as any event that requires a response or a deployment of their resources. These can include both emergency and non-emergency situations and may or may not be directly located on the roadway itself. For example, a building fire located adjacent to the roadway and an automobile crash located in the roadway are both defined as an incident, but can require completely different types of responses from an emergency service provider and can have a totally different impact on traffic operations.

Because of the subtle differences in the use of the term "incident," emergency responders and transportation officials are not always on the same page when it comes to talking about performance measures related to incidents and incident management. For the purposes of this white paper an incident is defined as follows:

> *… any event occurring in or adjacent to the highway right-of-way that affects or impedes the normal flow of traffic. Such events include traffic crashes, disabled vehicles, or spilled cargos in or adjacent to the travel lanes so as to reduce the available traffic-carrying capacity of the facility. It also includes events such as fires or emergency situations whose response might require the full or partial closure of the transportation network so that normal traffic patterns are disrupted, causing an abnormal increase on demand on other transportation facilities.*

While exhibiting many of the problems and involving many of the same players as traffic incident management, planned events such as highway reconstruction are assumed to fall under the auspices of special event management or work zone management. Catastrophic events, such as natural disasters and wide-scale evacuations, are generally not included within this definition of an incident because of the shear size and complexity associated with managing traffic during

these events. This is not to say, however, that incidents do not occur during the events. In fact, the planning associated with these disasters, special events, and work zones should consider how incidents are to be managed within the context of the event.

Use of Performance Measures in the Traffic Incident Management Process

Many agencies routinely collect and report statistics related to their incident management programs. Table 1 shows some of the more commonly collected statistics that are used to report on the performance of incident management systems throughout the United States. These statistics are often collected and reported on a monthly, quarterly, or annual basis. While these statistics help to quantify the magnitude of the incident problem and can be used in computing performance measures, they provide little direct insight into the effectiveness or performance of the incident management systems in a region. There is a need to move performance monitoring for an incident management system to the program and agency level.

Performance measurements and monitoring can be very powerful tools that can allow agencies to identify potential areas of improvement and provide agencies with a mechanism for gaining political support; however, few agencies use performance measurement and monitoring to their fullest potential. Recently, FHWA released the results of a self-assessment study on the use of performance measures in incident management systems (*4*). In the self-assessment, agencies were asked to rate, on a scale from 0 to 4, with 0 representing no progress in the area and 4 representing outstanding efforts in an area, the progress their programs are making related to the use of performance measures for incident management systems. The results of the self-assessment are shown in Table 2.

Clearly, the results of this self-assessment study show that agencies are not using performance measurement and monitoring to their fullest potential. This national survey shows that relatively few agencies have attempted to develop and use performance measures to track the effectiveness of their incident management programs. The survey suggests that there is a need to provide agencies with guidance on how to develop and use performance measures to better operate and improve traffic incident management in their region.

Measuring the Traffic Incident Management Process

Figure 1 shows the typical activities associated with responding to and clearing an incident. This figure shows one possible scenario of many for a typical response to a relatively minor incident. While the actual number of responders and the order in which they arrive on the scene is likely to vary from incident to incident, the same sequence of activities occurs with most incidents. These activities can be grouped into two categories: those associated with the emergency response to and clearance of the incident and those associated with managing the traffic and congestion in and around the incident scene. Performance measures are needed to quantify and assess the effectiveness of each group of activities.

Table 1. Commonly Reported Statistics Related to Incident Management System Performance.

Activity Type	Reported Statistic
Incident Management	• Total # of incidents • # of incidents by type (crashes, stalls, etc.) • # of incidents by vehicle type (cars, trucks, tractor-trailer rigs, etc.) • # of incidents by severity level (major, intermediate, minor) • # of incidents involving injuries and fatalities • # of incidents by surface condition (wet, dry, snowy, etc.) • # of incidents by day of week • # of incidents by period (AM, PM, off-peak) • # of incidents by time-of-day • # of incidents by blockage location (shoulder, right lane(s), left lane(s), etc.) • # of incidents by # of lanes blocked • # of incidents by milepost/facility • # of incidents by blockage duration • # of incidents detected by detection source (closed-circuit [CC]TV, service patrol, 911, etc.) • Average estimated detection time • Average response time (usually for first responder) • Average clearance time • Average total duration by incident type • Average total duration by severity level (major, intermediate, minor) • # of secondary crashes/incidents • Estimated reduction in delay (amount and cost) • Estimated reduction in fuel consumption (amount and cost) • Estimated reduction in emissions (HC, CO, NO)
Service Patrols	• # of assists by type (crashes, stalls, etc.) • # of assists by nature of assistance (fuel, tire change, etc.) • # of miles traveled • # of assists per miles traveled
System Coverage	• # of devices deployed by type (CCTV, loops, dynamic message signs [DMSs], etc.) • # of miles of roadway covered by devices • # (%) of devices operational by device type • # of hours operational by device type • # of DMS messages posted • # of web site hits • # of calls/assists dispatched by operators • # of false calls/gone on arrival calls/false alarms

Table 2. Results of Recently Completed Self-Assessment Study of the Use of Incident Management Performance Measures.

Question Number	Question	Average Score	% of Assessments Scores 3 or higher
4.1.3.1	Have multi-agency agreements on what measures will be tracked and used to measure program performance?	0.70	3%
4.1.3.2	Have agreed-upon methods to collect and analyze/track performance measures?	0.71	3%
4.1.3.3	Have established targets for performance?	1.25	4%
4.1.3.4	Conduct periodic review of whether or not progress is being made to achieve targets?	0.78	1%

Reference: (*4*)

Measures of Incident Responsiveness

Many incident management and emergency response agencies have been keeping records for years of their response times and time spent on-scene; however, with most systems today, it is difficult at best to track an individual incident through the management databases of all the different response agencies. Very few agencies today are capable of integrating the information contained in all of the emergency response management systems to allow agencies to develop a clear and comprehensive picture of how the incident response process performs in their region. A lack of common definitions and message formats and information privacy concerns have hindered this integration process. Standardization efforts like the Traffic Management Data Dictionary (*7*) and the IEEE 1512 Family of Standards for Incident Management (*8–11*) will make integration easier and more practical in the future.

Recently, the National Cooperative Highway Research Program (NCHRP) published *Research Result Digest 289 Measuring and Communicating the Effects of Traffic Incident Management Improvements* (*12*). The following measures were recommended as part of NCHRP *Research Result Digest 289* for measuring incident management programs:

- ***Average Detection Time –*** the estimated time from when the incident actually started to when the incident was detected by or reported to the first response agency involved in a coordinated traffic incident management program.
- ***Average Verification Time –*** the time from when an incident was detected by or reported to the first agency involved in a coordinated traffic incident management program to when the incident was verified by an agency involved in a coordinated traffic incident management program.
- ***Average Response Time –*** the time from when an incident was verified by an agency involved in a coordinated traffic incident management program to when the first responder arrived at the incident scene. This responder does not have to be the first one dispatched.
- ***Average Clearance Time –*** the time from when the first responder arrived at the incident scene to when the incident has been physically removed from the roadway environment.
- ***Effect of Incident on Traffic Conditions –*** the time from when the incident was estimated to have started to when the last responder leaves the scene of an incident.

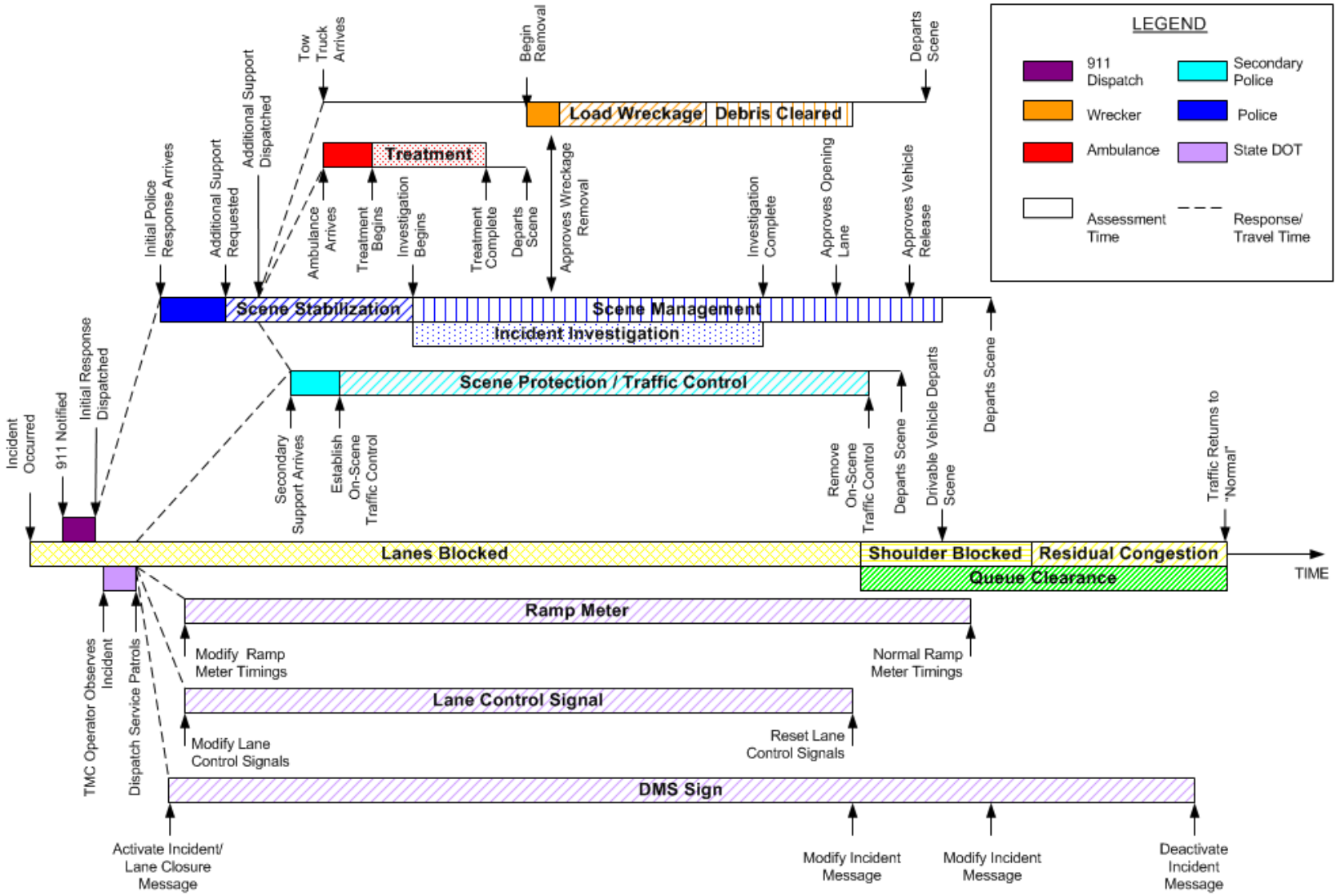

Figure 1. Timeline and Activities Associated a Typical Response to a Freeway Incident.

While many agencies are using these measures (or slight variations thereof) to assess the performance and effectiveness of their incident management processes, these measures do not always adequately capture the complexities of the incident response process, nor do they provide much valuable insight into how the incident management and response process can be improved. Take, for example, average detection time as discussed above. In the past, detection time was a major concern to operating agencies because without knowing when and where an incident occurred, agencies could not begin the response process. Today, with the proliferation of cellular telephones, 911 dispatching centers, and freeway surveillance systems, most major incidents in urban areas are reported within minutes (if not seconds) after they occur – either by those involved in the incident themselves or by other passing motorists. As a result, a major time lag between when an incident occurs and when response agencies are aware of it no longer exists in many areas. Coupled with the fact that agencies can do little to improve the detection process (an agency cannot make someone dial a telephone number quicker), the value of a performance measure focused on detection time is minimal.

Verification time is another example of a common performance measure that has little or no value to agencies wanting to improve their incident response process. Verification time is a hold-over from the days when transportation agencies used incident detection algorithms to detect congestion. Because of their propensity for false alarms, transportation agencies were hesitant to notify police or dispatch a response without visual confirmation of an incident through their surveillance systems. Because most incidents often generate multiple calls to 911 dispatching centers and because of liability issues, most 911 dispatching centers generally have a policy to dispatch a response to any perceived credible request for service. Therefore, visual verification by a department of transportation (DOT) agency is not required (although appreciated) before a response is dispatched. Because of the way most incident management systems operate today, verification time and response time are often one and the same. With most incidents, verification is often made by the first responder arriving on the scene.

Most emergency service agencies routinely monitor their own agency's response times to emergency calls. The issue is not only how quickly the first response agency knows about the problem but also how quickly all the response agencies know about the incident and get the appropriate response vehicles on-scene so that full operating capacity can be restored as quickly as possible. Therefore, it is not only important to measure the response time of the first responder (i.e., the time from when an incident was reported/detected to when the first official responder arrived on scene), but it is also important to measure the total response time (the time from when an incident was first reported to an appropriate response agency to when the last piece of needed response equipment arrives on scene).

Because of the complex interactions and potential number of responders in the incident response process, agencies should adopt the view of the traveling public when developing performance measures. From the traveling public's perspective, the general public wants to know that once the incident has been reported that all of the public response agencies are working to deploy the appropriate response personnel and equipment to preserve life and protect resources as quickly as possible to the incident scene. The public also expects agencies to know their business and to make a good faith effort to ensure that all the resources to clear the incident scene are present on-

scene when they are needed. When viewed from the perspective of the traveling public, there are three critical time elements to the incident response process:

- The time it takes for the first responder to arrive on scene after the incident has been reported;
- The time it takes to get all of the appropriate responders to the scene after an incident has been reported; and
- The time it takes to get the facility operating at its full capacity after the removal assets have arrived on-scene.

Figure 2 shows several proposed performance measures that agencies might want to consider using to assess the timeliness of the incident response process. Each of these measures is discussed below.

- ***First-Responder Response Time –*** This is a measure of the time it takes for the first responder to arrive at the incident after it has been reported to an official response agency. It is measured as the time difference between when the incident was first reported to or detected by an official response agency and when the first official responder arrives on scene. This measure is equivalent in definition to the response time performance measure proposed in NCHRP *Research Result Digest 289 Measuring and Communicating the Effects of Traffic Incident Management Improvements* (*12*).
- ***Notification Time –*** This is the time it takes for the all the appropriate response agencies to be properly notified of the incident situation and the required response is dispatched to the incident scene. It is measured from the time the report is first made to an official response agency to when all of the response agencies needed to respond to and clear the incident have been notified.
- ***Response Deployment Time –*** This measure represents the time it takes to deploy all of the equipment and personnel assets required to respond to and clear an incident scene. It is measured from the time that the incident was first reported/detected by an appropriate response agency to when the last response asset arrived on scene. This measure provides valuable insight into the level of planning and coordination that exists in the incident management process in a region because it measures the total amount of time needed to deploy all the assets required to clear an incident. It includes the time required for the first responder to assess the incident scene and determine what other resources are needed as well as the travel time of the response and clearance assets to travel to the incident scene.
- ***Clearance Time –*** This measure represents that amount of time needed to completely remove any wreckage and debris from the travel lane. It is measured from the time that the first incident responder arrives on scene to the time when all the wreckage and associated debris have been removed from the travel lane and the official on-scene management approves the reopening of the travel lane.
- ***Blockage Duration –*** This measure represents the amount of time that the incident blocked or impeded the travel way. It is measured from the time the first responder arrives on scene to when full capacity is restored to the travel way (i.e., the end of the clearance interval). It also includes the time required to remove any traffic control or scene protection that may block all or a portion of the travel way. Blockage duration can also include the time when activities on the shoulder are restricting flow past the incident scene (although this may be difficult to track in some locations).

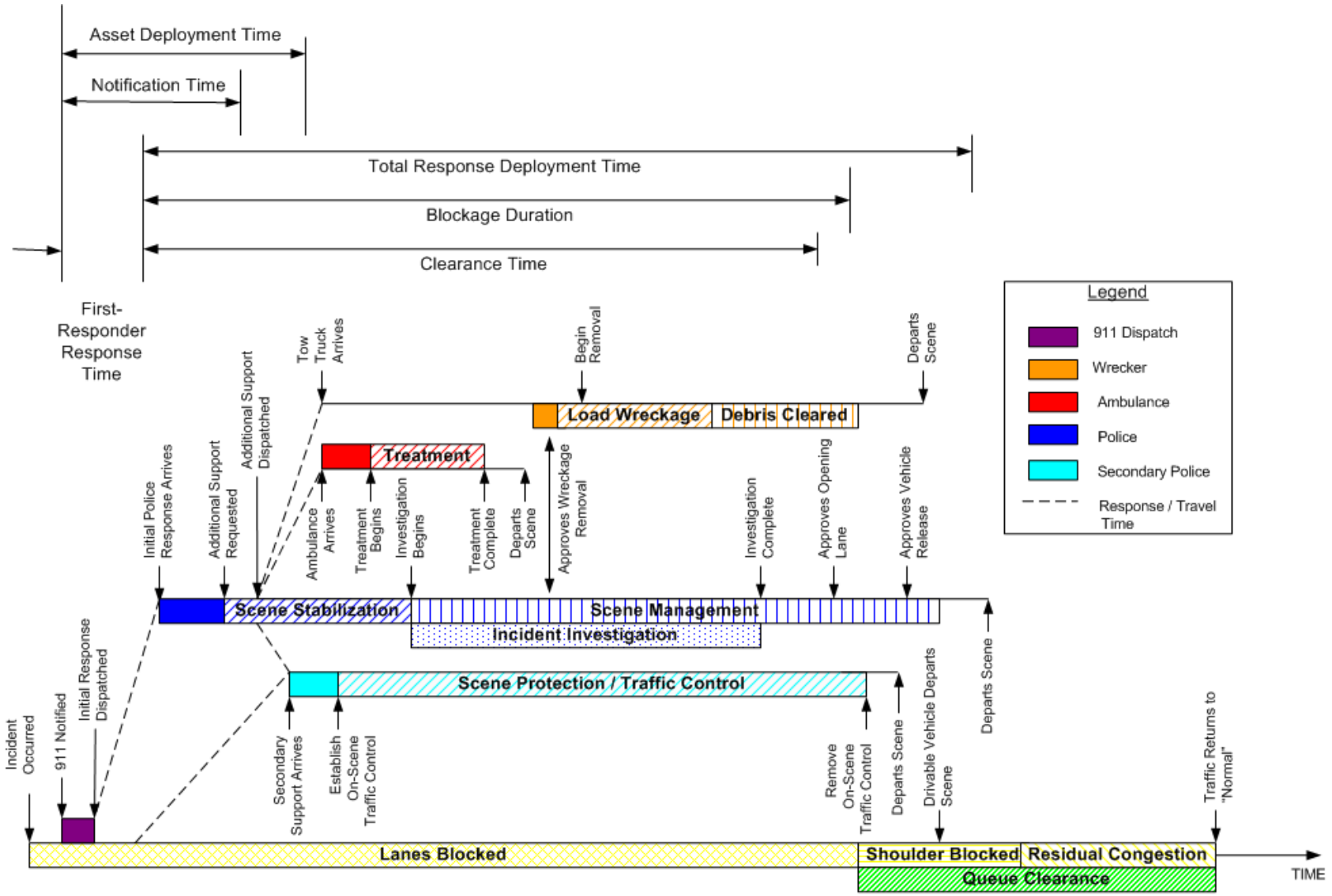

Figure 2. Candidate Measure for Assessing the Timeliness of the Incident Management Response in a Region.

- ***Total Response Deployment Time –*** Often, an incident responder will not immediately leave the scene of the incident once the travel way has been reopened; their duties and operating procedures require them to remain on-site until the vehicles themselves (or their occupants) have left the scene. This reduces their availability to assist in responding to other emergencies. This performance measure attempts to capture this. This measure represents the total amount of time that an incident response asset has been deployed on the scene. It is measured from the time that the first responder arrives on the scene to when the last incident response asset leaves the scene. It is intended to provide an indication of the amount of time that the incident keeps the response assets tied up at the scene and unavailable to respond to other emergency situations.
- ***Incident Duration –*** Recently, the National Transportation Operations Coalition (NTOC) Action Team on Performance Measurement released a report that documents measures commonly agreed upon by state, local, and federal transportation officials (*13*). In this report, incident duration is defined as "The time elapsed from the notification of an incident until all evidence of the incident has been removed from the incident scene." The units associated with this measure are "median minutes per incident." NTOC defines "notification" as being "receipt of the fact that an incident has occurred by any public agency personnel" (dispatcher, field vehicle, traffic operations center operator, etc.). NTOC also defines "evidence of the incident" to include "service vehicles, emergency vehicles, vehicles, and individuals involved with the incident and debris resulting from the incident."

One thing that has been missing with previous efforts to track incident response performance has been a single, common reference point from which to measure response times. In the past when transportation agencies were using manual observation and computer incident detection algorithms as the primary means of detecting incidents, agencies attempted to define the starting point for measuring incident response processes as the point from when the incident occurred. However, with the proliferation of cellular telephones and the development of 911 dispatching systems, it is not uncommon for incidents (particularly the more severe incidents involving collisions and possible injuries) to be reported to the emergency responders almost immediately after they occur.

Because the deployment assets needed to clear an incident will vary depending upon the severity of the incident type and location, agencies may want to implement incident severity classes (major, intermediate, and minor, as defined in the MUTCD [*6*]). For minor and some intermediate incidents, the first responder response and the response deployment times are likely to be the same time, but for major incidents involving multiple response agencies, the response deployment time can provide valuable insight into the level of planning and cooperation that exists in a region.

Measures of Asset Deployment

In most locales and for most incidents, DOTs play a support role in the incident management process. The main function of the DOTs in the incident process is to deploy the equipment, personnel, and other assets to manage traffic in and around the incident scene. DOTs need to

develop performance measures that allow them to assess how effective they are at deploying those traffic management assets.

The magnitude of the traffic management response varies depending upon the severity of the incident. For relatively minor incidents, on-scene responders, which are typically law enforcement and towing companies and occasionally highway agency service patrol vehicles, are primarily responsible for establishing traffic control associated with these incidents. Traffic diversion into other lanes is "often not needed or is needed only briefly," and "it is not generally possible or practical to set up a lane closure with traffic control devices for a minor traffic incident" (*6*). Therefore, from a traffic management standpoint, the DOT's response is generally limited to providing motorist notification through information devices on the roadway or through web sites. The critical element of performance, from the DOT's perspective, is how quickly the DOT can implement a message and notify the public of the incident after receiving notification of the incident.

The amount of assets that a traffic management agency deploys increases as the severity of the incident increases. For intermediate traffic incidents, DOTs may be asked to assist in establishing traffic control and lane closures in the immediate vicinity of the incident to provide better management of traffic through the incident scene and an increase in the level of on-scene protection for emergency responders. This may require the deployment of assets other than those typically used to manage minor incidents. For even more severe incidents, DOTs may be asked to establish or execute preplanned alternate routes to detour traffic around an incident scene. This may not only involve agencies to install and remove a greater number of traffic control devices, often over multiple routes, but it also may require DOT agencies to coordinate their response with other DOT agencies in the region. DOTs need measures that allow them to assess their performance in deploying traffic management assets in response to incident conditions.

Some potential measures that DOTs can used to evaluate their performance are listed below. Most of these measures again focus on how quickly agencies can deploy and remove traffic management resources to and from the incident scene.

- ***# of Incidents Classified as "Major," "Intermediate," or "Minor" –*** This represents the total number of incidents that fall within the MUTCD "Major," "Intermediate," and "Minor" classifications.
- ***% of Incidents Requiring Deployment of Traffic Management Assets –*** This is the ratio (expressed as a percentage) of the number of incidents to which a DOT is asked or required to deploy traffic management assets or implement diversion plans to the total number of incidents.
- ***DOT Notification Time –*** This represents the time between when the incident was first reported to an incident management responder to when it was reported/observed by the operators in the TMC.
- ***Time Required to Deploy Traffic Management Strategies or Resources –*** This measure is equivalent to the response times of the major emergency service providers. It represents the time from when the traffic management center was notified of the incident to when the appropriate traffic control was fully established on the scene. For minor incidents, this time might be the time it takes for the operator in the control center to develop and broadcast a

message on a dynamic message sign. For major incidents, this might be the time required to implement a preplanned diversion plan. The focus of this measure is not necessarily how quickly a response vehicle arrives on scene, but on how quickly an agency can make a determination as to the appropriate strategy for managing traffic around and through the incident scene and ultimately deploy that strategy.

- ***Asset Utilization Time –*** This is the time that a traffic management asset (such as a dynamic message sign, etc.) is used or deployed in the support of an incident response. It is intended to provide TMC operators and decision-makers with an idea of the duration their traffic management systems are used in support of traffic incident management functions. It can also be used to assess operator workload.
- ***Asset Removal Time –*** This is the time required to deactivate the traffic control devices and remove the diversion route after the incident has been removed. It is measured from the time the incident responder in charge of the incident scene indicates approval to clear to when the traffic control deployment has been fully removed.

Of particular importance for DOT agencies in dealing with intermediate incidents is keeping traffic control current with the changing traffic conditions. The MUTCD specifically states that "Attention should be paid to the end of the traffic queue such that warning is given to road users approaching the end of the queue" (*6*). It may be helpful for DOT operators and managers to know how frequently the queues extend past their established traffic control, how often they have to adjust their traffic control upstream, and how long it takes to affect these changes. DOTs can use the following suggested performance measures to provide this information.

- ***Average Queue Length –*** This measure is intended to provide agencies with a quantitative measure of the length of congestion associated with an incident. It can be estimated in terms of miles (to approximately ½ mile interval or so) that the queue or congestion related to an incident extended upstream of the incident location. While this measure, in and of itself, does not have much meaning, if this measure is coupled with other performance measures, such as incident type or time of day, it might prove useful in helping to determine where to initially establish traffic control for particular incident (given the importance afforded to managing traffic control measures near the end of the queue in the MUTCD).
- ***% of Incidents where Queue Extended Past Established Traffic Control –*** This measure represents the ratio (expressed as a percentage) of the number of incidents where the queue extends past the established traffic control to the total number of incidents. This performance measure could be used to identify potential flaws in the procedures and training needs for estimating queue lengths.
- ***% of Incidents Requiring Modification to Initial Traffic Control to Cover End of Queue –*** This measure represents the ratio (expressed as a percentage) of the number of incidents where the DOT had to modify the initial traffic control because of changing traffic conditions to the total number of incidents. This measure can be used to assess personnel and resource requirements to keep traffic control strategies consistent with changing traffic conditions.
- ***Time Required to Effect Change to Traffic Control Set Up to Adjust for End of Queue –*** This is the time that is needed to affect a change in traffic control set up because of changing traffic conditions. This measure can be used to assess personnel and resource requirements to keep traffic control strategies consistent with changing traffic conditions.

The above-listed performance measures are particularly important for those agencies that are currently looking to establish wide-scale deployment of traffic management assets (such as dynamic message signs, lane control signs, etc.). These measures can potentially be used to adjust the efficiencies from reduced personnel and equipment that can be achieved through deployment of these devices.

Measures Response Effectiveness

While the above performance measures allow those responsible for managing the incident response to detect potential deficiencies in their system (i.e., where response can be improved), they tell little of overall impact and effectiveness of the response on traffic operations. In addition to those measures discussed above, agencies need to develop performance measures that allow them to gauge the overall effectiveness of the incident response.

To be effective and useful for agencies, these measures need to be more focused on the type and quality of service that agencies provide. As such, these types of measures are more user- or customer-oriented and focus on the impact that the traffic incident management response has on the travel of the individual or the motoring public as a whole. They are intended to assess the overall effectiveness of the incident management program to improve efficiency in traffic flow and safety and/or enhanced customer satisfaction. Agencies can use the measures to determine if the incident response process has its desired result (or outcome) on traffic operations. These measures generally tend to be targeted toward high-level policy- and decision-makers that assess the economic benefits and returns of a program. Many of these measures are difficult to measure directly but require computer simulation or another tool to estimate.

NCHRP *Research Result Digest 289* (*12*) suggests the following user-oriented performance measures might be suitable for assessing the impact and effectiveness of traffic incident management programs:

- ***Travel Time Index –*** This is the ratio of the actual travel to free-flow conditions for the time period being considered. Travel conditions are defined in terms of the travel rate (the inverse of speed) weighted by vehicle-miles traveled (VMT) for ease of computation. The index can be applied to various system elements with different free-flow speeds. Index values can be related to the general public as an indicator of the length of extra time spent in the transportation system during a trip.
- ***Buffer Index –*** This is the amount of extra "buffer" time that a traveler needs to allot to arrive "on-time" 95 percent of the time (i.e., late 1 day per month.) As such, it is a measure of travel time reliability. Indexing the measure provides a time- and distance-neutral measure, but the actual minute values (i.e., the 95^{th} percentile) could be used by an individual traveler for a particular trip length. The index can be calculated for each road segment, and a weighted average is calculated using vehicle-miles of travel as the weighting factor.
- ***Total Delay Due to Incidents –*** This measure represents the total number of vehicle-hours (or person-hours) lost because travel was adversely affected by congestion caused by the incident. Delay is measured relative to free-flow conditions. Generally, this delay is difficult to measure directly in the field but can be estimated using computer simulation or manual calculations after the incident occurs

- ***Fuel Savings Due to Traffic Incident Management –*** This measure represents the estimated amount of fuel that is saved as a result of implementing traffic management strategies in response to the incident. To determine savings, a user would need to estimate the amount of fuel expended during the incident both with and without the incident management strategies deployed. Fuel consumption estimates would need to be derived from a computer simulation model.
- ***Safety Benefits –*** This measures the reduction in primary and secondary incidents due to rapid response and identification of problem areas to be solved by geometric or operational improvements.

In addition to those measures proposed in NCHRP *Research Result Digest 289* (*12*), other potential measures that can be used to assess the effectiveness of the incident management response process in a region include the following:

Travel Mobility and Congestion

- ***Incident Rate –*** This measure is intended to quantify the magnitude of the number of incidents that occur in a region. Similar in concept to an accident rate, this measure can be determined by computing the ratio of the number of incidents to the vehicle miles traveled. This measure can be computed per facility or per period. Agencies can use this measure to assist them in determining where to deploy limited incident management resources.
- ***# of Hours Facility Operating at Less than Full Capacity Due to Incident Conditions –*** This measure is intended to represent the amount of time that an individual facility is not operating at its full capacity due to incident conditions. Before and after comparisons of this measure can be used to assess the relative impact of response improvements or traffic management strategies. It can be expressed either as a numerical value or a percentage of the total time. This measure can be reported as an annual, monthly, or daily measure. This measure is computed per facility or per period.

Travel Reliability

- ***Average Duration Traveler Spends in Incident Conditions –*** This measure is intended to represent the amount of time that an individual traveler spends traveling in incident conditions. This measure can be computed on either an annual or per trip basis. It can be computed by estimating the number of hours that an individual in a region spends traveling in incident conditions compared to the total number of hours the average persons spends traveling. This measure can be computed for a region as a whole or on a per facility basis.
- ***Average # of Minutes Added by Incident to Typical Trip Travel Time –*** This measure is similar in concept to the buffer index but is intended to capture the number of minutes that is added to a driver's individual trip time if they become caught in an incident. It can be computed by taking the difference between the average travel time during incident conditions and the average travel time during non-incident conditions. This measure can be reported by time-of-day or for specific travel periods (such as peak periods).

Safety

- ***# of Secondary Incidents –*** This is a measure of the number of incidents that occur as a result of or in the vicinity of (either in physical proximity and/or within a defined interval of time) a previously occurring incident (or primary incident). Strategies and tools need to be developed that allow agencies to associate and store incidents that are secondary in nature to the primary events.
- ***Probability or Likelihood That Individual Incident Will Cause Secondary Incident –*** This measure is intended to capture the probability or likelihood that a secondary incident will occur as a result of the first incident. This involves estimating or quantifying the number of secondary incidents that are associated with an earlier incident. It is expected that the probability of a secondary incident occurring would be greater the more frequent and the longer incidents occur. Agencies can use this measure to potentially quantify the safety benefits of reducing the total duration that an incident is present on a facility.

Agency Efficiency and Productivity

- ***% of Time an Asset is Deployed at Traffic Incident Conditions –*** The longer response assets (particularly emergency service providers) are deployed on-scene at an incident, the less time that they are available to handle other potential emergencies. Therefore, in terms of asset management, agencies may want to reduce the amount of time that their assets are tied up responding to incidents. This measure can be computed by accumulating the total number of hours that equipment and personnel assets are being utilized to manage incident conditions. Before and after comparisons of this measure can be used to assess the effectiveness of improvements to shorten the amount of time responders spend on-scene at an incident.
- ***% of Resources Expended on Traffic Incident –*** Agencies can quantify what percentage of their personnel and equipment resources are expended in managing incidents. This measure can be computed in terms of monetary value or in time. These costs can be compared to the total operating budget for an agency or program budget to show the amount of resources consumed as a result of responding to or managing incidents. This measure could be used potentially to illustrate the need for additional funding or expansion of program resources needed to support expansion of an existing traffic incident management program.

Customer Satisfaction

Agencies should not overlook the value of customer satisfaction ratings as a way of collecting measures about their performance related to managing traffic during incident conditions. From a motorist's perspective, reasonable travelers want to know that agencies are doing everything within their power, first to ensure their safety as they approach an incident scene and second, to notify them of the situation and potential travel alternatives and routes. To gauge whether or not agencies are meeting these expectations, agencies may want to establish a focus group or develop a web page where motorists can grade their performance on how they are handling incident situations. Through this mechanism, agencies can ask questions and solicit feedback to ascertain the public's perception of how agencies are performing during incident conditions. A sampling of the types of questions that might be included in this feedback mechanism is provided below.

- How would you rate the performance of the DOT in responding to and clearing incidents?
- When an incident occurs, do you feel that you have been adequately notified of the following:
  - Location
  - Duration
  - Expected impacts
- What are we doing well? What are we doing not so well?
- Where do we need to improve?
- What are your suggestions for improving the quality of service we provide to you?
- Do you feel that the DOT is meeting your expectations in providing quick responses to incidents?
- Do you feel that the DOT is meeting your expectations in adequately informing you of when and where incidents are occurring and their impact?
- Do you feel that the DOT is meeting your expectations in addressing your safety concerns in and around incident scenes?

Issues Affecting Implementation

The following provides several issues that agencies need to address in going forward with implementing a performance measurement and monitoring system with a more regional perspective.

Performance measures need to reflect the programmatic nature of incident management. Cooperation and coordination between and within agencies is critical to the successful implementation of a traffic incident management program. Successful traffic incident management programs often combine numerous technologies, devices, and resources that collectively are used to detect, respond to, and clear incidents as well as manage traffic upstream and downstream of the incident location. Performance measures need to be developed that capture the effectiveness of the wide ranges of strategies and techniques that are often employed.

Performance measures need to reflect the multi-agency nature of incident management. The measures that are used to assess effectiveness need to allow agencies to gauge their relative contribution and impact on the incident management process. They need to be sensitive enough to allow agencies to gain valuable insight into how the incident management and response process is working and help decision-makers see where and how improvements to the system can be made. In order for this to occur, there is a need to more closely integrate and openly share information and data between response agencies.

Agencies need to recognize that multiple sets of performance measures may be needed for different elements of the incident management process and for different target audiences. From a DOT perspective, multiple elements exist to the incident management process in which agencies may want to track performance: a response element (i.e., those activities associated with getting resources to the scene to clear an incident), a clearance element (i.e., how long it took for those resources to clear the blockage), a site management element (i.e., those activities associated with the emergency responders), a traffic management element, and a recovery element (i.e., traffic management strategies that can be deployed to aid in dissipating the queue

once the incident is clear). Multiple performance measures may be needed to track improvements geared toward monitoring and correcting deficiencies associated with each element. However, from a programmatic standpoint, these measures not only need to focus on the individual elements themselves (i.e., how quickly agencies deploy the necessary and appropriate assets to the incident scene) but also the inter-relationships and communications aspect associated with coordinating operations between all the appropriate agencies.

Agencies should limit the number of performance measures to those that are most meaningful, represent their highest priorities or most critical needs, and reflect local community goals and desires. It is easy to develop copious numbers of performance measures that provide little direct insight into the performance of the traffic incident management program. Agencies frequently examine what data other agencies collect and assume that these are the most appropriate for their region. Because these measures do not necessarily reflect the common goals and desires of all the agencies involved, many agencies find that the usefulness of the measures diminishes over time. To keep performance measurement meaningful, agencies should collectively identify one or two areas that have the greatest potential to see significant change and/or improvement and develop performance measures that focus on those aspects. The performance measures that are used to assess the effectiveness of the change should be meaningful to all agencies involved in the incident response process.

Local agencies need to view performance measures and performance monitoring as a resource for improved decision-making and not just a reporting requirement. One criticism often used against using performance measures is that they can be used to make direct (and sometimes unfavorable) comparisons of an agency's operation with those of another jurisdiction. Agencies need to adopt the view point that performance measurement and monitoring are tools that allow them to identify where changes need to be made and the result of those changes. Agencies should use performance measures in a non-threatening and non-accusatory way to identify problems and show the effectiveness of improvements.

Agencies need to set reasonable and attainable performance targets. Having a series of performance measures without performance targets is like having a roadmap with no destination in mind. One critical step in having a useful and meaningful performance measurement and monitoring system is to establish clear, reasonable, and attainable performance goals or targets. Many locations are beginning to use performance targets as a tool to help them assess the effectiveness of their incident response process. Both the States of Washington (*14*) and Florida (*15*) have established a performance target that all major incidents will be cleared within 90 minutes of when they occur. These agencies have developed measurement systems and regularly report on the ability to achieve this performance target.

Performance measures need to be periodically and routinely reviewed at all levels in an organization. Regardless of the measures ultimately used to assess performance, agencies need to establish a process for regularly reviewing (or benchmarking) performance. Benchmarking is the process of routinely collecting and reporting information and data on the effectiveness of a system or process. In incident management, benchmarking serves two important functions. First, benchmarking allows agencies to identify and focus on potential areas for improvement. Before agencies can talk about where the incident management process can be improved, data and

information need to be collected to show how the system is currently performing. It is difficult to determine where you need to go and how you need to get there if you do not know where you are. Benchmarking provides a framework for developing a program or path for continuously improving performance in an incident management program. It also allows agencies to generate political and institutional support for the improvements to the program.

Benchmarking also provides agencies with a point of reference from which changes and improvements to a system can be judged. For example, if agencies take actions and expend capital funds that are intended to reduce overall incident response times, then they need to know what their current response times are in order to determine whether or not the improvement was successful. Benchmarking allows agencies to quantify and compare the effectiveness of operational changes in the detection, response, and clearance processes.

References

1. *Traffic Congestion and Reliability: Linking Solutions to Problems*. Prepared by Cambridge Systematics and the Texas Transportation Institute, July 2004. Available at http://www.ops.fhwa.dot.gov/congestion_report/index.htm. Accessed March 13, 2005.
2. *Traffic Incident Management Handbook*. Prepared by PB Farradyne, November 2000. Available at http://www.itsdocs.fhwa.dot.gov/jpodocs/rept_mis/@9201!.pdf. Accessed March 13, 2005.
3. *Incident Management* Webpage. Office of Operations, Federal Highway Administration. Available at http://ops.fhwa.dot.gov/incidentmgmt/index.htm. Accessed March 2, 2005.
4. *Traffic Incident Management Self Assessment* Webpage. Office of Operations, Federal Highway Administration. Available at http://ops.fhwa.dot.gov/incidentmgmt/tim_selfassess.htm. Accessed March 2, 2005.
5. *Performance Measurement Fundamentals* webpage. Office of Operations, Federal Highway Administration. Available at http://ops.fhwa.dot.gov/perf_measurement/fundamentals.htm. Accessed March 15, 2005.
6. Chapter 6I. Control of Traffic Through Traffic Incident Management Areas. In *Manual on Uniform Traffic Control Devices for Streets and Highways.* 2003 Edition Including Revision 1 dated November 2004. Federal Highway Administration, US Department of Transportation. Available at http://mutcd.fhwa.dot.gov/pdfs/2003r1/pdf-index.htm. Accessed March 2005.
7. *Standard for Functional Level Traffic Management Data Dictionary (TMDD).* ITE-AASHTO TM 1.03. Available at http://www.trafficincident.org/tmdd/index.asp. Accessed August 3, 2005.
8. *Common Incident Management Message Sets for Use by Emergency Management Centers*. IEE Std. 1512-2000. Institute of Electrical and Electronics Engineers, New York, NY. July 2000.
9. *Traffic Incident Management Message Sets for Use by Emergency Management Centers.* IEE Std. 1512.1-2003. Institute of Electrical and Electronics Engineers, New York, NY. March 2003.
10. *Public Safety Incident Management Message Stets for Use by Emergency Management Centers.* IEE Std. 1512.2-2002. Institute of Electrical and Electronics Engineers, New York, NY. 2002 (Draft).
11. *Hazardous Material Incident Management Message Sets for Use by Emergency Management Centers.* IEE Std. 1512.2-2002. Institute of Electrical and Electronics Engineers, New York, NY. October 2002.
12. *Measuring and Communicating the Effects of Traffic Incident Management Improvements.* NCHRP Research Result Digest Number 289. Transportation Research Board, Washington, DC. Available at http://gulliver.trb.org/publications/nchrp/nchrp_rrd_289.pdf. Accessed May 2005.
13. *National Transportation Operations Coalition Performance Measures Initiative. Final Report.* July 2005. Available at http://www.ntoctalks.com/ntoc/ntoc_final_report.pdf. Accessed August 2, 2005.
14. *Washington State Department of Transportation Accountability* Website. Available at http://www.wsdot.wa.gov/accountability/default.htm. Accessed August 3, 2005.

15. *State of Florida "Open Roads Policy"*. Available at http://www.dot.state.fl.us/trafficoperations/incidentmanagement/incident_main.htm. Accessed August 3, 2005.